SHOUT
SHARE
IT

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 562

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER September 15, 1917

THE CONTROL OF TOBACCO WILT IN THE FLUE-CURED DISTRICT.[1]

By W. W. Garner, *Physiologist in Charge of Tobacco Investigations, Bureau of Plant Industry;* F. A. Wolf, *Plant Pathologist and Bacteriologist, North Carolina Agricultural Experiment Station;* and E. G. Moss, *Assistant in Tobacco Investigations in the Bureau of Plant Industry and Collaborator of the North Carolina Agricultural Experiment Station.*

[In cooperation with the North Carolina Agricultural Experiment Station.]

CONTENTS.

	Page.
Importance of the disease	1
Symptoms of tobacco wilt	3
Leaves	3
Stalk	3
Roots	3
Cause of the disease and its present distribution	4
Susceptibility of species and varieties of tobacco to the wilt	5
Relation of the physical and chemical properties of the soil to the wilt	7
Crop rotation as a basis for the control of the wilt	10
Crop-rotation experiments at Creedmoor, N. C.	10
Length of rotation required to reclaim infested soils	15
Precautions to prevent the spread of the disease	17
Summary	18
Literature cited	20

IMPORTANCE OF THE DISEASE.

Tobacco wilt is a very serious disease in portions of the flue-cured district of Virginia and the Carolinas, the cigar-leaf district of

[1] This bulletin presents the results of investigations conducted jointly by the North Carolina Agricultural Experiment Station and the Bureau of Plant Industry for the purpose of working out practical methods for the control of tobacco wilt. The experiment station began studies to this end in 1903 and the work has been continued from that time. In 1910 cooperation with the Office of Tobacco Investigations, Bureau of Plant Industry, was effected, and the scope of the work was considerably extended. On behalf of the experiment station, the work has been directed successively by Dr. F. L. Stevens, Prof. H. R. Fulton, and one of the present writers. Messrs. W. G. Sackett, J. G. Hall, E. H. Cooper, R. O. Cromwell, W. C. Norton, and E. E. Stanford, assistants at the experiment station, have actively participated in the investigations.

western Florida and southern Georgia, and in several foreign countries. The disease was first brought to public attention in this country in 1903, when its occurrence in Granville County, N. C., was described in separate publications by R. E. B. McKenney (5),[1] of the Bureau of Plant Industry of the United States Department of Agriculture, and F. L. Stevens and W. G. Sackett (10), of the North Carolina Agricultural Experiment Station. Because of the possible existence of other tobacco wilts Stevens and Sackett designated the disease in question "Granville wilt," from the name of the county in which it was first definitely recognized. Additional information regarding the occurrence and nature of the disease is contained in a bulletin by Erwin F. Smith (7) which appeared in 1908.

It is not known when the wilt first appeared in the flue-cured district of southern Virginia and the Carolinas, but it seems to have been known to the farmers of Granville County at least as early as 1881. As a result of extensive investigations in this country and in the Dutch East Indies and Japan, it appears to have been definitely established that a wilt of tobacco which has long existed in the latter countries is identical with the Granville wilt (8).[2] In this country, tobacco growers in sections where the disease is known speak of it simply as tobacco wilt, and this name is retained in the present bulletin.

Since it first came under observation in Granville County, the wilt has continued to spread, and usually when a field once becomes infested subsequent crops of tobacco are increasingly attacked until a practically complete failure of the crop results. The wilt is an exceedingly destructive disease locally, and in the southern portion of Granville County it has caused the abandonment of tobacco culture on many farms. The disease has been most destructive in the region which enjoys the reputation of producing the finest quality of flue-cured tobacco grown in the country, and the aggregate loss to farmers is very large, although difficult to estimate accurately. The loss is serious every year, although varying considerably, depending on seasonal conditions. The plants are killed outright and a loss of 25 to 40 per cent is not unusual, while on many fields the crop is practically a total loss. Should the disease become destructive throughout the flue-cured district it would practically stop the production of this type of tobacco, the annual value of which is 30 million dollars.

---

[1] Serial numbers in parentheses refer to "Literature cited," page 20.

[2] The disease in Sumatra appears to have been first studied by Janse (4) in 1892 and later by Van Breda de Haan (1) and Honing (2), who spoke of it as a "slime sickness." According to Uyeda (11) the disease is known in Japan as stem-rot, black-leg, and wilt disease and was mentioned in a book on tobacco culture published in 1881.

SYMPTOMS OF TOBACCO WILT.

The disease affects the entire plant, leaves, stem, and roots, in a characteristic manner. It may attack plants in any stage of development, but usually symptoms first appear two to four weeks after transplanting. During the period of rapid growth which follows as soon as the tobacco plants have become established after transplanting, the number of wilted plants increases rapidly, reaching the maximum at about the usual time for topping. Under certain conditions there are exceptions to this progressive increase of wilt.

LEAVES.

The first decided indication of the presence of wilt is the drooping of one or more leaves of the plant. This wilting usually comes on gradually, requiring several days to become prominent, and growers familiar with the disease are often able to detect the first symptoms of wilting a day or two before the layman would observe anything unusual about the plant. Affected leaves also may be somewhat distorted and wrinkled. At first there is no discoloration, but the leaves soon become pale green, especially between the larger veins, and then the leaf gradually turns yellow. Meanwhile the midrib and the veins have become limp and droop in a characteristic, umbrellalike manner, which persists even after the leaves and the stalk become brown and crisp. In some cases the leaves on one side of the plant wilt first, and sometimes only half the leaf is affected at first.

STALK.

In the early stages of wilt, if the tobacco stalk is cut across with a knife the woody portion shows a yellowish discoloration, which becomes brownish or black as the disease progresses, especially in the lower part of the stalk. By stripping off the bark the discoloration appears as longitudinal streaks. In the advanced stages the pith also becomes affected. The inner bark also decays, and as the wet rot extends outward dry, blackened areas appear on the surface of the stalk. Pressure on discolored stalks will force out from the cut ends an opaque, dirty white ooze, very different in appearance from the normal cell sap.

ROOTS.

The organism causing the disease enters the plant through the roots, so that by the time the leaves begin to wilt the roots will show more or less decay. When cut across with a knife the affected roots in the earlier stages will show a dark discoloration in the woody por-

tion lying near the bark. This discoloration appears as longitudinal streaks in this portion of the root, just as it does in the corresponding part of the stalk. In the early stages of the disease only a few of the roots are attacked, but eventually the whole root system is involved.

There are other diseases of tobacco involving decay of the stalk, especially the so-called sore-shin, or sore-shank, which have been mistaken for the wilt, but the presence of a characteristic slimy ooze when the stalk is cut and the black streaks in the woody portion are usually sufficient to distinguish the wilt from other diseases. In typical sore-shin, moreover, the stalk rots near the base, causing the plant to topple over.

CAUSE OF THE DISEASE AND ITS PRESENT DISTRIBUTION.

Tobacco wilt is caused by *Bacterium solanacearum* E. F. S. This is a well-known organism, first studied by Dr. Erwin F. Smith (6), which causes a destructive rot of the tomato and Irish potato and attacks many other plants besides these and tobacco. In infected tobacco plants the bacteria soon become so abundant in the woody vessels that these become plugged, thus cutting off the water supply of the leaves, thereby causing them to wilt. If only the vessels on one side of the plant first become clogged, then only the leaves on that side of the plant will at first wilt. Naturally, with the water supply cut off, no further development of the leaves is possible and the plant must soon die. Various theories as to the cause of tobacco wilt have been put forward by farmers, and it has been believed by many that the fertilizers used on the tobacco crop have been responsible in some way for the appearance of the disease. It is true that fertilizers, cultural methods, weather conditions, and the like may influence the extent of progress of the disease, but, as already indicated, there is no doubt whatever that the disease is due to a specific parasite.

As has been stated, tobacco wilt, though designated by other names, has long been known in Sumatra and Java and in Japan. In this country it was first found in Granville County, N. C., but about 10 years ago it made its appearance in the cigar-tobacco district of Gadsden County, Fla., and Decatur County, Ga., probably having been introduced there through tobacco stems used as fertilizer which came from the wilt district of North Carolina. For a number of years the disease in Granville County was confined to the southern portion of the county lying between the Tar and Neuse Rivers. This happens to be the section enjoying the reputation of producing the finest flue-cured tobacco grown in this country. Within this area

the spread of the disease has been rather rapid, so that now but few farms are free from it. The disease has not spread so rapidly outside of this section, although it has long since crossed the above-mentioned rivers. It has reached the adjoining counties of Vance, Durham, Wake, and Franklin and also has been found in Ashe, Guilford, Greene, Chatham, Davidson, and Yadkin Counties. It is quite possible that tobacco wilt also exists in other sections of the flue-cured district. Although the outward spread of this wilt is not particularly rapid, its progress is none the less certain, and once established it is exceedingly persistent and exceptionally destructive.

SUSCEPTIBILITY OF SPECIES AND VARIETIES OF TOBACCO TO THE WILT.

In dealing with the problem of control the first line of attack was the search for resistant varieties of tobacco. The simplest solution, of course, would be the discovery of a resistant type in the standard native varieties used in growing flue-cured tobacco. Failing in this, the next step would be to find a resistant type among the numerous varieties used in growing other classes or kinds of tobacco which are produced in this and foreign countries. If such a resistant type could be found, it could be crossed with the native flue-cured varieties with a fair prospect of obtaining a new variety combining the resistant properties of the foreign with the commercial qualities of the native varieties. For several years past extensive tests have been made with nearly all available varieties, including many from foreign countries, but while some varieties have been found to be less susceptible than others the resistance was not sufficient to meet practical requirements. Although the final results were negative, it seems desirable to summarize briefly the work along these lines. In making the tests the general plan has been to grow the different varieties in rows side by side on soil known to be badly diseased, including occasional rows of a standard native variety, so as to measure the relative degree to which the different parts of the field were diseased. Records of the number of healthy plants and the number dead or wilted were made at intervals during the growing period, the last records being taken when the plants had reached maturity.

In the first tests, made in 1904, 62 varieties or types known by distinctive varietal names were used.[1] These included some 25 subvarieties or strains of Oronoco, several of the Pryors, White Burley, Maryland, the Broadleaf, or Seedleaf, and Havana Seed types of the northern cigar-leaf districts and domestic and imported

[1] For further details of the tests, see Stevens, F. L. (9).

Cuban, Turkish, and Sumatra tobaccos. Practically all domestic types of tobacco were represented, but none showed a high degree of resistance, 70 to 90 per cent of the plants succumbing to the disease. Work with local flue-cured varieties has been continued up to the present. Each year seed from plants which had survived in the previous year's test has been planted, but no progress has been made in developing a resistant strain. In the tests with foreign varieties, including varieties from South America, Mexico, Cuba, Sumatra, Turkey in Asia, Turkey in Europe, Italy, and Russia, it was found that the Sumatra, a Turkish variety from Cavala in Macedonia, and a variety from Italy designated by Comes as *Nicotiana tabacum fruticosa* showed considerable resistance to the wilt, and selections from these were grown for several years. The Sumatra and Turkish were crossed also with the local flue-cured type in an effort to develop a highly resistant commercial variety. The most striking feature of these experiments was the fact that the resistance of the above-mentioned varieties depends largely on seasonal conditions. Under conditions tending to produce slow growth, particularly dry weather, these varieties have shown a relatively high degree of resistance, and in some years less than 10 per cent of the plants died. Under conditions favoring rapid growth, especially periods of wet weather, on the other hand, nearly all plants died. No highly resistant types were obtained from any of the hybrids.

A type of imported Cuban tobacco showed a resistance of 12 per cent in 1911, 96 per cent in 1912, 78 per cent in 1913, and 46 per cent in 1914, variations apparently due to seasonal conditions. Taking the tests as a whole, the Sumatra variety has shown the highest resistance of all varieties. In this connection it should be stated that Honing (2), working along the same lines in Sumatra, tested varieties from various parts of the world, including 30 or more American varieties, and found none more resistant than the native Deli (Sumatra). The Halladay, a type developed in Connecticut from a cross of Sumatra on Connecticut Havana, also has shown considerable resistance in the present tests.

Since the investigations failed to show sufficient resistance in any of the varieties of tobacco belonging to the ordinary species grown in America (*Nicotiana tabacum*), it seemed worth while to test various other species, wild and cultivated. Tests were made with several varieties of *Nicotiana rustica* from Italy, Russia, China, and elsewhere, but all of these were found to be very susceptible. Other species tried were *longiflora*, *glauca*, *glutinosa*, *langsdorfii*, *silvestris*, *affinis*, and *sanderae* (hybrid), none of which showed higher resistance than the ordinary tobaccos.

RELATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL TO THE WILT.

The second line of attack in searching for a practical method of controlling the wilt was to determine whether the soil could be treated by chemical or physical methods which would destroy the organism causing the trouble or weaken its activity. In 1904 a series of field plats on infested soil at Creedmoor, N. C., was given various chemical treatments before being set to tobacco. Heavy applications of powerful disinfectants, including several salts of copper, formalin, corrosive sublimate, permanganate of potash, carbolic acid, iron sulphate, and sulphur, were tried. Strong acids and alkalis and excessive applications of potash, nitrogen, and phosphoric acid also were tested. None of the treatments gave any promise of success in practical tobacco culture. In 1910 another series of field tests with chemicals was made on a diseased field near Creedmoor, including a more extensive study of the effect of acid and alkaline conditions on the disease. The effects on the wilt of soluble forms of calcium, magnesium, silicon, aluminum, iron, and manganese were tested, but without results, these tests being based on the assumption that the wilt is not to be feared in soils containing large amounts of clay. Various fertilizer treatments were tried, only materials tending to produce alkaline conditions being used on some plats, while on others only substances favoring an acid reaction were employed. For example, one plat received per acre 200 pounds of carbonate of potash, 600 pounds of basic slag, 250 pounds of nitrate of soda, 500 pounds of cottonseed meal, and 2,000 pounds of burned lime, while another received equivalent amounts of sulphate of potash, acid phosphate, ammonium sulphate, and acid sodium sulphate. None of these treatments produced any decided effect on the amount of wilt.

In the following year, in order better to control the experimental conditions, a large number of glazed-tile cylinders 2½ feet long and 2 feet in diameter were set in the ground so as to leave about 3 inches projecting above the ground level. The cylinders were installed at West Raleigh and at Creedmoor. The pots were filled to a depth of about a foot with bottom earth taken from the holes in which the pots were placed, after which about 8 inches of subsoil and 8 inches of topsoil from a diseased tobacco field at Creedmoor were added. All tests were made in duplicate and each cylinder contained four plants. In continuation of previous work, tests were made with mixtures of varying proportions of sandy and clay soils; with ordinary wilt soil, to which were added separately the chief chemical constituents of clay; with plants grown from seeds without transplant-

ing, so as to avoid breaking the roots; with acid reagents and alkaline reagents; and with various chemical disinfectants. Considerable difficulty was experienced in maintaining the infection in the cylinders, because of their becoming excessively dry or from some other unfavorable condition, so the results were rather inconstant and uncertain. The results of tests covering three years, mixtures of sandy and clay soils being used, seemed to indicate that the wilt organism is not very active in clayey soils, but none of the chemical constituents of clays applied singly to sandy soils appeared to have any decided action on the organism. A rather extensive series of tests was made with acids and alkalis. For the former sulphuric acid, acid potassium sulphate, and nitric acid were used, and for the latter quicklime, calcium carbonate, potassium carbonate, sodium silicate, and sodium carbonate were employed. In most cases at least two different rates of application were made. The results of tests covering three years indicate in general that alkalis are favorable to the wilt organism, while acids retard its development, but the results were not very constant and failed to furnish any basis for a practical remedy. Details of the tests are shown in part in Table I. Each cylinder should have contained four plants, but it will be noted that the stand was poor, due largely to the toxic action of the chemicals applied to the soil.

TABLE I.—*Tests of tobacco plants grown in cylinders containing soil treated with acids and with alkalis at West Raleigh and Creedmoor, N. C., in 1913 and 1914.*

Cylinder No. and location of test.[1]	Soil treatment.	1913.—Number of plants.		1914.—Number of plants.	
		Wilted.	Healthy.	Wilted.	Healthy.
11 and 18	Acid potassium sulphate, 17 grams	None.		None.	3
11 and 13 (Creedmoor).	Acid potassium sulphate, 85 grams	2	6		
35 and 42	Sulphuric acid, 1 ounce in 6 quarts of water	2			
46	Sulphuric acid, 2 ounces in 6 quarts of water.	None.		None.	3
38 and 43	Nitric acid,[2] 1 ounce in 6 quarts of water	4		None.	5
14 and 21	Lime carbonate, 600 grams	1		1	4
4 (Creedmoor)	Quicklime, 300 grams	3	1		
10 (Creedmoor), 12 (Creedmoor). 17 and 24	Potassium carbonate, 70 grams	9			
12 and 19	Sodium carbonate, 300 grams	4			
15 and 22	Sodium silicate, 17 grams	1		2	2

[1] Tests located at West Raleigh, except as otherwise stated.
[2] Cylinder No. 38 received 4 ounces of nitric acid and cylinder No. 43 received no acid in 1914.

In the cylinder tests with disinfectants, use was made of formalin, potassium permanganate, chlorid of lime, atomic or superfine sulphur, β-naphthol, Bordeaux mixture, and a number of proprietary preparations, mostly coal-tar products, many of them in varying rates of application. No decidedly beneficial results were obtained.

During the four years, 1911 to 1914, inclusive, field plats at Creedmoor, N. C., consisting of single rows, were used in trials with disinfectants. The usual fertilizing and cultural methods were followed alike on all plats. The results for 1911 and 1912 are shown in part in Table II. The permanganate of potash and chlorid of lime were applied in the same quantities and in double the quantities recommended by Honing in Sumatra, the weaker solutions consisting of 125 grams of the chemical in 25 gallons of water. The solutions were poured into the holes in which the plants were to be set 24 hours before transplanting.

TABLE II.—*Field experiments with tobacco plants, showing the effects of soil disinfectants at Creedmoor, N. C., in 1911 and 1912.*

Year of tests and chemicals used.	Method and rate of application.	Number of plants.		Percentage of wilt.
		Wilted.	Healthy.	
Tests in 1911 (condition on Aug. 12):				
Check		30	1	96.8
Potassium permanganate	Weak solution, 2 quarts per hill.	39	4	90.7
Check		29	2	93.5
Chlorid of lime	Weak solution, 2 quarts per hill.	27	3	90
Check		23	3	88.5
Potassium permanganate	Strong solution, 2 quarts per hill.	32	2	94.1
Check		25	0	100
Chlorid of lime	Strong solution, 2 quarts per hill.	17	1	94.4
Tests in 1912 (condition on Aug. 5):				
Check		5	37	11.9
Toluol	50 gallons per acre	27	35	43.5
Check		38	17	69.1
Toluol	25 gallons per acre	39	22	63.9
Check		35	19	64.8
Toluol	100 gallons per acre	40	18	69
Check		40	12	76.9
Check		26	19	57.8

In 1913 and 1914 the experiments were continued along the same lines, with the use of formalin, sulphuric acid, naphthol, carbolic acid, Bordeaux mixture, atomic sulphur, lime sulphur, coal tar, pine tar, and several proprietary disinfectants. In these tests more than a score of germicides and other chemicals were applied in various quantities and in various ways. Since the same plat was used each year, the cumulative effect of the chemicals was detrimental to the growth of the tobacco. Here, as in the cylinders, it was difficult to secure a good stand of plants. In general, there have been no consistent differences in the percentages of wilt in the treated and the untreated rows. The results are confirmatory of the cylinder tests and do not promise success in wilt control through the use of chemicals. In 1915 certain materials supposed to contain radium, including Banque du Radium, carnotite, and a radioactive earth, were tried in several differing quantities at Creedmoor, but without any definite results.

It should be added finally that in view of the theory entertained by some that lack of drainage or aeration in the soil is a cause of wilt, experiments were made on the effects of deep plowing and subsoiling, but the results were entirely negative. Dynamiting the soil according to methods recommended was tried, with a view to destroying any hardpan or impervious layer beneath the topsoil, but no beneficial action could be noted.

CROP ROTATION AS A BASIS FOR THE CONTROL OF THE WILT.

It has been seen that so far as known all species and varieties of tobacco, both wild and cultivated, are readily destroyed by the wilt, and it is well known that other plants belonging to the same family are seriously attacked. Obviously none of these plants should be grown on tobacco land affected with wilt. The parasite, however, is by no means limited to solanaceous plants, and is now known to attack members of no less than nine distinct families of the higher plants, namely, (1) Solanaceæ (including tobacco, Irish potato, pepper, eggplant, jimson weed, etc.), (2) Leguminosæ (including the peanut), (3) Balsaminaceæ, (4) Compositæ (including the common ragweed), (5) Euphorbiaceæ, (6) Pedaliaceæ, (7) Tropæolaceæ, (8) Urticaceæ, and (9) Verbenaceæ. It is probable that further search will show that still other plants are attacked by this organism. Outside of the Solanaceæ the peanut and the ordinary ragweed are of special importance in the flue-cured district. In parts of the district peanuts are an important money crop and the ragweed (*Ambrosia artemisiæfolia*) is extremely common on tobacco lands throughout the district. Peanuts must be avoided and the ragweed kept down if rotation of crops is to be effective in controlling the wilt.

CROP-ROTATION EXPERIMENTS AT CREEDMOOR, N. C.

Beginning with 1911, experiments on the effectiveness of crop rotation for the control of tobacco wilt have been conducted on a tobacco field near Creedmoor, N. C., on which tobacco was practically a total failure in 1910. The soil in this field is the Granville coarse sandy loam and is rather uniform throughout except for a gall spot of several square yards on the plat designated "F" in figure 1. The plats slope away gently on either side of the turn row, which extends through the center of the field. The drainage is good on all plats except for small areas on the southern edge of plat 1 and on the northern edge of plat 4, and there is but little chance for surface drainage from one plat to adjoining ones.

In these experiments the rotation and cropping systems included nearly all of the more important crops adapted to the section, namely,

FIG. 1.—Plan of the experiment field at Creedmoor, N. C., showing details of the cropping system on each plat. Plats B, C, D, E, and F were planted to tobacco in 1916.

tobacco, corn, cotton, peanuts, wheat, sweet potatoes, cowpeas, mixed clovers, and grasses. Two different types of cropping were followed. In the first type a single crop or group of crops was grown continuously on the same plat. Thus, corn was grown continuously on a quarter-acre plat for five years, with crimson clover as a winter cover crop. In the same way, peanuts and sweet potatoes were each grown continuously on separate plats for five years, in each case with rye as a winter cover crop. Wheat, followed by cowpeas cut for hay, also was grown continuously on one plat. On one plat a mixture of mammoth or sapling clover, redtop, orchard grass, and tall meadow oat-grass was grown each year, the plat having been reseeded in 1913. A plat cropped continuously to cotton was started two years later and thus far has run only three years. For comparison, tobacco was grown each year on one plat, with rye and crimson clover as a winter crop. In 1916 tobacco was grown on all plats to determine the effects of the other crops on the wilt. There were two objects in the continuous cropping to the same crop plants each year. In the first place it was not certain at the outset which of the crops are immune to the wilt, and, secondly, it was desired to determine by direct test the comparative values of the different crops in reducing the amount of wilt. This plan was fully justified by later development, for it was soon found that peanuts are quite susceptible to the disease, while, on the other hand, the remaining crops proved to be about equally effective in reducing the injury from the wilt, thus indicating that they are immune.

In the second type of cropping, a system of rotation including corn, wheat and cowpeas, red clover and grass, and tobacco was followed on a series of plats. In this series it was arranged that after

the first three years half of one of the plats would come into tobacco each year, while the other half would be kept in other crops for another series of years. This arrangement served to furnish light as to the number of years of cropping to immune crops that is required to bring the wilt under control. The general arrangement of the various plats and the system of cropping on each are shown in detail in figure 1. Cotton was not originally included in the tests, and the intention was to use rotation plat 1 for other purposes; but beginning with 1913 half of this plat was cropped to cotton each year and the other half used as a check plat, being cropped to tobacco every year. After it was observed in 1912 that the peanuts on plat C were seriously affected with wilt, a portion of this plat was used in succeeding seasons for making certain tests on the susceptibility to wilt of varieties of tomatoes. The acre plat shown in the figure was used for the tobacco variety tests already discussed. A line of tile cylinders used in the tests with chemicals and disinfectants occupied the eastern edge of plat A. The results of the cropping tests are expressed in percentages, which were arrived at by making counts of the numbers of healthy and diseased plants on each plat at the time of maturity. These results are brought together in Table III.

TABLE III.—*Results of 5-year cropping and rotation tests for the control of tobacco wilt at Creedmoor, N. C., in 1916.*

Designation of plat.	Number of plants.		Percentage of wilt.
	Healthy.	Wilted.	
Plat B (sweet potatoes continuously)	927	249	21.2
Plat C (peanuts continuously) [1]	475	649	57.7
Plat D (corn continuously)	1,146	44	3.7
Plat E (red clover and mixed grasses continuously)	1,106	57	4.9
Plat F (wheat and cowpeas continuously)	1,010	65	6
Rotation plat 4–A	871	107	10.9
Plat 1–B (tobacco continuously)	165	717	81.3

[1] A portion of plat C was cropped to tomatoes in 1913, 1914, and 1915.

Table III shows that on plat 1–B, cropped to tobacco each year, 81 per cent of the plants showed wilt in 1916. Figure 2 gives a good idea of the extent of the wilt on this plat. A large proportion of the diseased plants on plat 4–A were found in a poorly drained corner on the northern edge. Barring this corner, there was only about 5 per cent of wilt on this plat, which had been rotated in corn, wheat, cowpeas, grass, and clover for five years. It will be noted also that on plats D, E, and F, which had been cropped to corn, clover and grass, and wheat and cowpeas, respectively, for five years, there was only 4 to 6 per cent of wilt, so that the loss was

P2064T

FIG. 2.—A field showing the results of continuous tobacco cropping, Creedmoor, N. C. Tobacco was grown on this plat each year from 1911 to 1916, inclusive. Fully 80 per cent of the plants showed wilt on July 27, 1916. (Plat 1–B.)

negligible. The effectiveness of grass and clover and of corn in reducing the injury from wilt is shown in figures 3 and 4, respectively. It should be noted, however, that the tobacco made a much better growth after grass and clover than after corn. On plat C, one portion of which had been cropped to peanuts and the other to tomatoes, 58 per cent of the plants were affected. The portion of the plat on which tomatoes had been grown showed about 20 per cent more wilt than the portion cropped to peanuts. Figure 5 clearly shows the marked injury from wilt on this plat. The tobacco was mature and ready for harvesting by July 27, and on that date there was only 5 per cent of wilt on plat B, which had been cropped to sweet potatoes continuously for five years. The tobacco was allowed to stand, however, and on August 10 symptoms of wilt were shown by 21 per cent of the plants, while no such marked increase occurred in the other plats. A similar condition was noted on plat 1–B in 1915, for on August 3 there was only 3 per cent of wilt, while on August 11 there was 23 per cent. The normal, gradual progress of the wilt in a tobacco field is shown in Table IV, which gives the counts on the plats made from June 29 to August 10, 1916. No wilted plants were observed a week prior to June 29.

TABLE IV.—*Rate of wilting of tobacco in plats at Creedmoor, N. C., in 1916.*

No. of plat.	Number of plants wilted.								
	June 29.	July 1.	July 5.	July 6.	July 7.	July 8.	July 13.	July 27.	Aug. 10.
Plat A	62	83	183	209	232	246	320	453	568
Plat B	5	8	15	17	.....	18	25	62	249
Plat C	69	95	141	155	187	209	245	414	649
Plat D	7	10	13	18	.....	19	23	44	.....
Plat E	7	9	13	18	.....	22	24	57	.....
Plat F	2	5	9	12	.....	14	30	65	.....
Plat 1–B	112	157	249	324	371	396	534	660	717
Plat 4–A	4	.....	9	10	.....	15	35	95	107

The results of the experiments at Creedmoor extending through the past six years thus show beyond doubt that growing corn, wheat, cowpeas, clover, and mixed grasses (redtop, tall meadow oat-grass, and orchard grass), either singly or in a regular rotation, for a period of five years on badly diseased soil will reduce the loss from tobacco wilt to the point where it is almost negligible. Sweet potatoes (but not Irish potatoes) also will greatly reduce the loss from wilt, although they may be somewhat less effective for the purpose than the above-named crops. Peanuts, on the other hand, have practically no value in reducing the loss from the tobacco wilt and should not be grown on infested tobacco soils. The tests with cotton have not yet been completed, but the experience of others in the wilt section seems to leave no doubt that this crop is immune to the wilt and is to be classed with corn, wheat, and grass in this respect.

FIG. 3.—Tobacco growing after grass and clover, Creedmoor, N. C. This plat was in grass and clover for five years, 1911 to 1915, inclusive. Only 4½ per cent of the plants showed wilt on July 27, 1916. (Plat E.)

FIG. 4.—Tobacco growing after corn, Creedmoor, N. C. This plat was cropped to corn for five years, 1911 to 1915, inclusive, with crimson clover as a winter cover crop. Less than 3 per cent of the plants showed wilt on July 27, 1916, but it should be noted that the tobacco is decidedly smaller in size than that after grass and clover (plat E). (Plat D.)

Another important lesson from the experiments is that, other things being equal, injury from wilt is likely to be much greater on poorly drained spots; hence, crop rotation may be less effective under these conditions.

LENGTH OF ROTATION REQUIRED TO RECLAIM INFESTED SOILS.

In the preceding pages it has been demonstrated that under proper conditions the growing for a period of five years of crops not attacked by the wilt organism will make it possible, even on the worst infested fields, to produce a crop of tobacco with only a very small loss from wilt. This would mean a 6-year rotation, or 1 acre of tobacco every year for each 6 acres of tobacco land on the farm. In most cases the farmer will want to grow a larger acreage of tobacco; hence, it is important to know the shortest practicable rotation for controlling the wilt. As was explained on page 11, the rotation plats at Creedmoor were so arranged that after the third year half of one plat came into tobacco each year, and the system of cropping was that shown for rotation plats 2, 3, and 4 in figure 1 (p. 11). These experiments furnish data on the comparative effects of cropping three, four, and five years, respectively, with crops not attacked by wilt. The results are brought together in Table V.

TABLE V.—*Condition of tobacco on plats of wilt-infested land at Creedmoor, N. C., which had been planted to crops not affected by the wilt for three, four, and five years, respectively.*

No. of plat and year of test.	Period of cropping with immune crops.	Number of plants.		Percentage of wilt.	
		Healthy.	Wilted.	In rotation plat.	In check plat cropped to tobacco continuously.
Plat 2–A, 1914	3 years	359	52	12.6	53
Plat 3–A, 1915	4 years	680	159	18.9	72
Plat 4–A, 1916	5 years	871	107	10.9	81

In these tests, the check plat on which tobacco was grown every year indicates that the wilt was not so destructive in 1914 as in the following two years. In the rotation plat for 1915 it should be stated that on August 3 only 3 per cent of the plants showed the wilt, while only a week later, when the final count was made, 18.9 per cent of the plants were affected. It is evident that the effectiveness of the rotation will depend to some extent on the seasonal conditions, but the growing of immune crops for four or five years probably will reduce the loss from wilt to a minimum even on very badly infested fields. On such fields it is believed that three years of such cropping will not be sufficient to bring the wilt under satisfactory control.

P2086T

FIG. 5.—Tobacco growing after peanuts and tomatoes, Creedmoor, N. C. All of this plat was cropped to peanuts in 1911 and 1912; in the three following years a portion of the plat was cropped to peanuts and a portion was planted in tomatoes. On the plat as a whole 58 per cent of the plants showed wilt on July 27, 1916. There was somewhat more wilt after tomatoes than after peanuts. (Plat C.)

although the loss would be greatly reduced, as shown by the results for 1914.

After the disease has been brought under control, it is thought that a good crop of tobacco can be grown every fourth or fifth year. Under no circumstances should a crop of tobacco be followed directly by a second one. Farmers are strongly advised against doing this, no matter how effectively the wilt may have been brought under control, for by this procedure the beneficial effects of the rotation will be largely undone and a correspondingly longer period of rotation will be required to restore the soil.

PRECAUTIONS TO PREVENT THE SPREAD OF THE DISEASE.

Although the rotation of crops makes it possible to grow tobacco on land infested with wilt, those farms in the wilt area that are still free from the disease command a considerable premium, because a larger acreage of tobacco can be grown on them. It is clearly to the interest of the owner to use every possible means of keeping his farm free from the tobacco wilt. Thorough burning of tobacco seed beds will destroy the wilt parasite, but the seed bed may become reinfested if diseased soil from surrounding fields, even in very small quantities, is allowed to reach the bed after it has been sterilized. The seed bed, as well as the field, also may become infested by surface drainage from infested fields. This explains the frequent observation by farmers that wilt may appear in the first crop of tobacco grown on freshly cleared lands, a fact which should serve as a warning of what may be expected if the surface drainage from neighboring wilt-infested farms is allowed to reach noninfested tobacco lands. For the above reasons tobacco growers are advised to avoid setting in fields free from infestation plants obtained from seed beds which may be infested. A half dozen infected plants may easily be the means of establishing the wilt permanently on a plantation.

There is no reason for supposing that the disease is carried over in the seed, and there is no doubt that the two principal sources from which healthy fields receive the disease are (1) soil from infested fields and (2) diseased tobacco plants, either living plants or the dead material of leaf, stem, stalk, or root. Infested soil carried on a plow borrowed from a neighbor or on the feet of an animal or of a man may serve to introduce the disease. In the process of flue curing it might be expected that the comparatively high temperatures used toward the end of the curing would be sufficient to kill the parasitic organism, but cases have been observed in Granville County in which it is highly probable that the wilt was introduced on tobacco farms through the use of stems as a fertilizer. It is not advisable to use tobacco stalks or stems from diseased fields on lands not already infested with wilt, since the curing process can not

be relied upon in all cases to sterilize these materials. Finally, tobacco growers are advised to practice rotation of crops on their tobacco lands as a means of preventing the wilt, for if the soil is exposed to infestation the disease is less likely to become established when a systematic rotation of crops is followed.

SUMMARY.

In this country, tobacco wilt was first reported from Granville County, N. C., in 1903. Subsequent investigation has shown that the same disease, designated by other names, was already known in Sumatra and Java and in Japan. Tobacco wilt is an exceedingly destructive disease, causing the plant to die outright and frequently resulting in a practically complete failure of the crop.

The wilt produces definite symptoms in the leaves, the stalk, and the roots of the tobacco plant. The more prominent features are a characteristic umbrellalike drooping of the leaves, the presence of a yellowish to black discoloration in the woody portion of the stalk (showing as streaks when the bark is stripped off), the presence of a slimy ooze when the stalk is cut across with a knife, and a decided decay of the root system.

Tobacco wilt is caused by *Bacterium solanacearum* E. F. S., which also causes a destructive rot of the tomato and Irish potato and attacks many other plants. The organism enters the plant through the root and eventually brings about a plugging of the vessels, thus cutting off the water supply from the leaves and causing them to wilt and perish. Fertilizers, cultural methods, weather conditions, and the like may influence the extent or progress of the disease, and it has been observed that it is decidedly more destructive in relatively wet seasons.

For a time the wilt was confined to the southern portion of Granville County, N. C., but it has since spread into the adjoining counties of Vance, Durham, Wake, and Franklin and also has been found in Ashe, Guilford, Greene, Chatham, Davidson, and Yadkin Counties, N. C. The wilt also has become established in the cigar-tobacco district of western Florida and southern Georgia.

In efforts to find a tobacco resistant to wilt, numerous species and varieties, both wild and cultivated, from various parts of the world have been tested, but no species or variety has been found which is sufficiently resistant to meet practical requirements. The Sumatra and certain crosses of Sumatra with Connecticut cigar types were found to be relatively more resistant than the other forms tested.

Experiments have been carried on for several years to determine whether the wilt could be controlled by chemical or physical treatment of the soil. Various acids, alkalis, and neutral salts, including fertilizer materials, were applied to the soil by varying methods and

in varying quantities. Tests were made with a large number of germicides, including standard copper and mercury compounds, formalin, carbolic acid, and other well-known organic and inorganic germicides, in addition to numerous proprietary products. Finally, subsoiling with the plow and by the use of dynamite was tried as a possible remedy for the wilt. In none of these tests were the results sufficiently encouraging to hold out hope of controlling the disease by any of the treatments employed.

Crop rotation was the only method tested which gave satisfactory results in controlling tobacco wilt. By cropping badly infested land for five years with crops not affected by wilt the injury to the tobacco from the disease was reduced from 80 to less than 10 per cent.

The wilt germ attacks a number of plants other than tobacco, and these plants must be kept off the land if the rotation is to be effective. For this reason tomatoes, Irish potatoes, and peanuts should not be grown on tobacco lands; and since ragweed, which is a very common weed in the flue-cured district, is attacked, it is important that this weed be kept down.

The crops tested which gave satisfactory results for the practical control of the wilt are corn, wheat, rye (as a cover crop), sweet potatoes, cowpeas, grasses, red clover, and crimson clover. There is good evidence tending to show that cotton[1] also is not affected by tobacco wilt, and there is no reason for supposing that oats are affected.

From the tests conducted at Creedmoor, N. C., when taking into account the differences in the amount of wilt due to varying weather conditions, it appears that on badly infested land the growing of crops not attacked by wilt for four or five years will give better results than only three years of such cropping, although the 3-year period greatly reduced the amount of wilt. It is believed that on badly infested soils a crop of tobacco should not be grown oftener than once in every five years, but after the disease has been brought under control tobacco probably may be grown safely every fourth year. Under no circumstances should two crops of tobacco be grown in succession on infested soil.

To keep the wilt off farms not already infested, it is recommended that seed beds be thoroughly burned to insure complete sterilization and that care be taken not to allow surface drainage from infested farms to reach the seed bed or the tobacco land. Great caution should be used in securing plants or farming implements from farms on which the wilt is present. Tobacco stalks or stems from infested farms should not be used as a fertilizer on healthy soils. Every effort should be made to prevent infested soil or diseased plant material in any form from reaching the farm.

[1] Results obtained since the text of this bulletin was written have shown that cotton is immune to the tobacco wilt.

LITERATURE CITED.

Breda de Haan, J. van.

(1) 1898. De slijmziekte bij de tabak in Deli. *In* Teysmannia, deel 8, p. 528–550.

Honing, J. A.

(2) 1910. De oorzaak der slijmziekte en proeven ter bestrijding. *In* Meded. Deli Proefstat. Medan, jaarg. 5, afl. 1, p. 1–24, 2 fold. tab.

(3) 1914. Onderzoekingen over de virulentie van bacillus solanacearum tegenover verschillende nicotiana-soorten en variëteiten. (Experiments on the virulence of Bacillus solanacearum against different nicotiana species and varieties.) [In Dutch and English.] Bul. Deli Proefstat. 2, 15 p. Literatuur, p. 15.

Janse, J. M.

(4) 1892. Nota over eene ziekte der tabak op Sumatra. *In* Teysmannia, deel 3, p. 653–662.

McKenney, R. E. B.

(5) 1903. The wilt disease of tobacco and its control. *In* U. S. Dept. Agr., Bur. Plant Indus. Bul. 51, p. 5–8, 1 fig.

Smith, Erwin F.

(6) 1896. Bacterial disease of the tomato, eggplant, and Irish potato. U. S. Dept. Agr., Div. Veg. Physiol. and Path. Bul. 12, 28 p., 2 pl. (1 col.).

(7) 1908. The Granville tobacco wilt. U. S. Dept. Agr., Bur. Plant Indus. Bul. 141, p. 17–24.

(8) 1914. Bacteria in relation to plant diseases. v. 3. Washington, D. C. (Carnegie Inst. Washington Pub. 27.)

Stevens, F. L.

(9) 1906. Report of the biological division. *In* N. C. Agr. Exp. Sta. 28th Ann. Rept. [1904]/05, p. 25–29.

——— and Sackett, W. G.

(10) 1903. The Granville tobacco wilt; a preliminary bulletin. N. C. Agr. Exp. Sta. Bul. 188, p. 81–96, 15 fig.

Uyeda, Y.

(11) 1905. Bacillus nicotianae, sp. nov.; die Ursache der Tabakwelkkrankheit oder Schwarzbeinigkeit in Japan. *In* Bul. Imp. Cent. Agr. Exp. Sta. Japan, v. 1, no. 1, p. 39–57, pl. 4–8 (partly col.).

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽